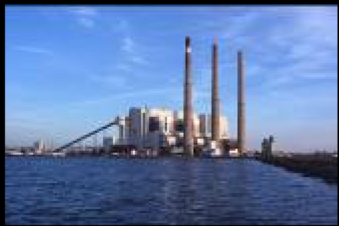



An Integrated Approach to Boiler Optimization

Presented by:

Joe Naberhaus – Dynegy

Peter Spinney – NeuCo

Reinhold NOx Roundtable & Expo

February 6, 2007

DYNEGY

NeuCo

The Optimization Standard™

Agenda

- **Optimization Overview**
- Integrated Boiler Optimization
- Boiler Optimization Project at Baldwin

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Role of Optimization

- The process of turning reams of complex data into **action**able knowledge that delivers **bottom line** benefit

- An Optimizer Must:
  - **ACT:** continuously identify actions that can improve asset performance
  - **INFORM:** provide insight into what actions were taken or advice given and why
  - **QUANTIFY:** the benefits & missed opportunities

Data Sources:

ERPs (e.g. SAP)
CMMSs (e.g. Maximo)
Monitors (e.g. GeneralPhysics)
Analyzers (e.g. Zolo)
Detectors (e.g. SmartSignal)
Historians (e.g. OSI)
DCSs (e.g. ABB)

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Types of Optimizers

- **NeuCo currently has 4 commercially-available Optimizers:**
  - **CombustionOpt®:** Optimizes fuel & air mixing to lower emissions and improve heat rate
  - **SootOpt®:** Optimizes sootblowing activity to improve reliability, heat rate and emissions
  - **PerformanceOpt®:** Identifies efficiency and capacity bottlenecks and the actions required to control the corresponding losses
  - **MaintenanceOpt™:** A diagnostics center for the detection, diagnosis and prioritization of maintenance problems
- **And there are more on the way:**
  - DOE CCPI-2 NRG Texas Limestone
  - Customer Teaming

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Importance of an Integration Platform

- Integrating disparate data and knowledge sources
- Standardizing metrics allowing performance comparisons and tradeoffs across equipment, units and plants
- Coordinating actions towards common business objectives, instead of competing
- Prioritizing the most important actions you can take to achieve your objectives
- Creating transparency and accountability by bridging islands of information and understanding

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Agenda

- Optimization Overview
- **Integrated Boiler Optimization**
- Boiler Optimization Project at Baldwin

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What does Integrated Boiler Optimization Mean?

- Integrated optimal operation of combustion, boiler cleanliness, steam temperatures, and total boiler performance
- Real-time management of multiple objectives, constraints, and tradeoffs:
  - Monetized objectives
  - Coordination of individual Optimizers toward global objectives
  - Sharing real-time knowledge between multiple solutions
    - CombustionOpt
    - SootOpt
    - PerformanceOpt
    - MaintenanceOpt
- Recognition that priorities and operating conditions change in dynamic and complex ways

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Integrated Boiler Optimization Benefits

- Ensuring that total operating costs are minimized in face of changing conditions and cost factors
- Adhering to all applicable constraints
- Integration of real-time operations with maintenance needs
- Managing tradeoffs between instantaneous and longer-term costs and financial performance
- Making the whole more than the sum of the parts!

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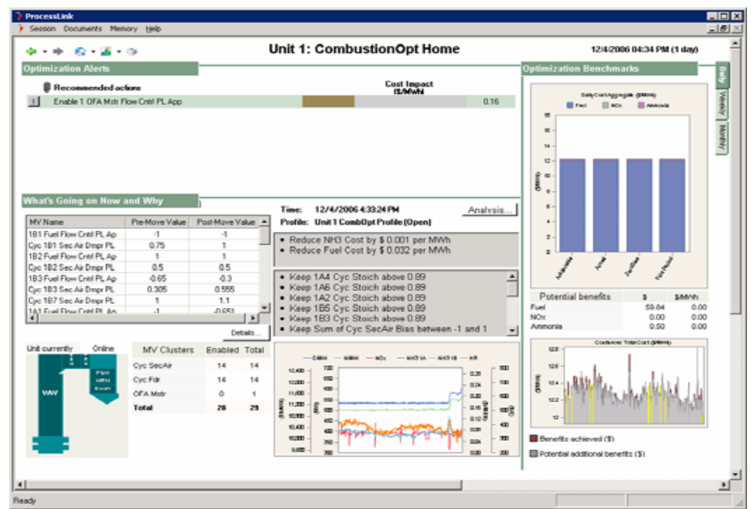
Boiler Optimization Components

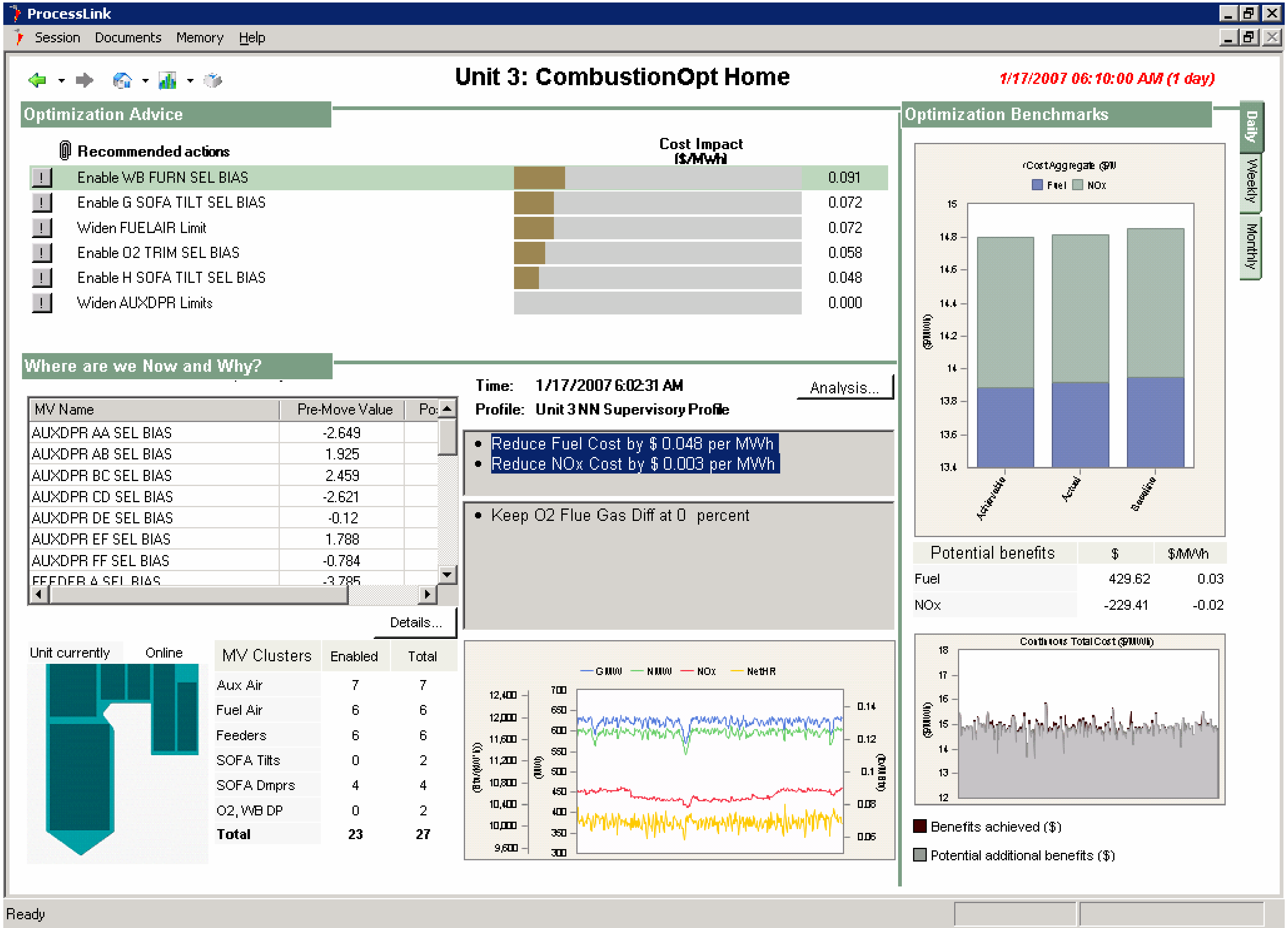
- Optimizers
  - CombustionOpt
  - SootOpt
- Technologies
  - Neural Networks
  - Model Predictive Control
  - Expert Systems/Heuristics
  - Simulation Engine
  - Integrated Object Library
  - Analysis Tools

CombustionOpt Overview

- **Context:**
  - Combustion controls manipulate a few variables (such as O2) as a function of load, leaving 35-100 fuel and air injection points that significantly impact combustion performance to infrequent offline tuning or operator tweaking
- **What CombustionOpt Does:**
  - Provides real-time closed-loop optimization of fuel and air mixing by manipulating all relevant fuel and air injection points
- **Using:**
  - Neural network and model predictive control technologies
- **To Achieve:**
  - NOx, heat rate, steam temp, CO and opacity improvements



CombustionOpt Home



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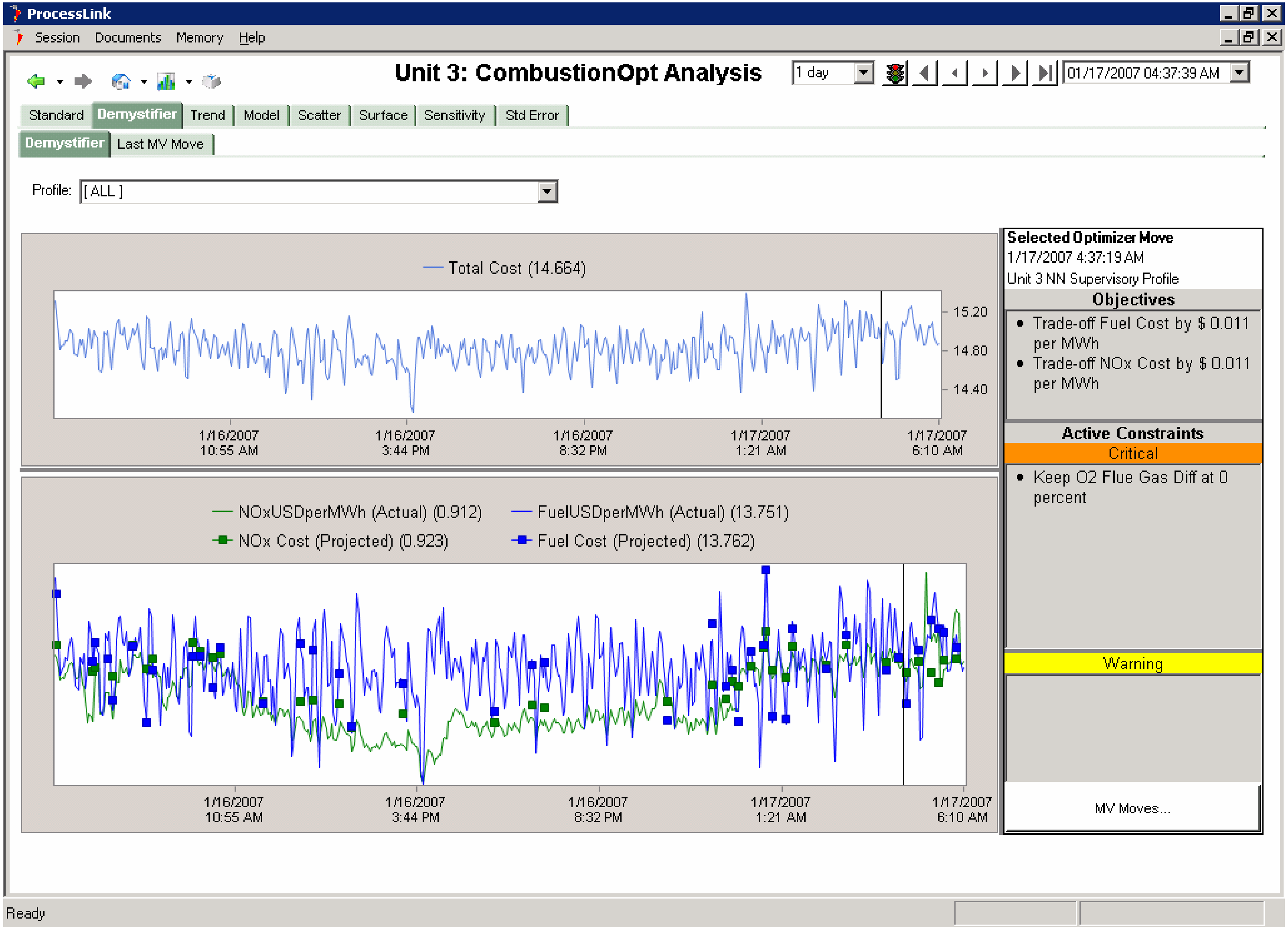
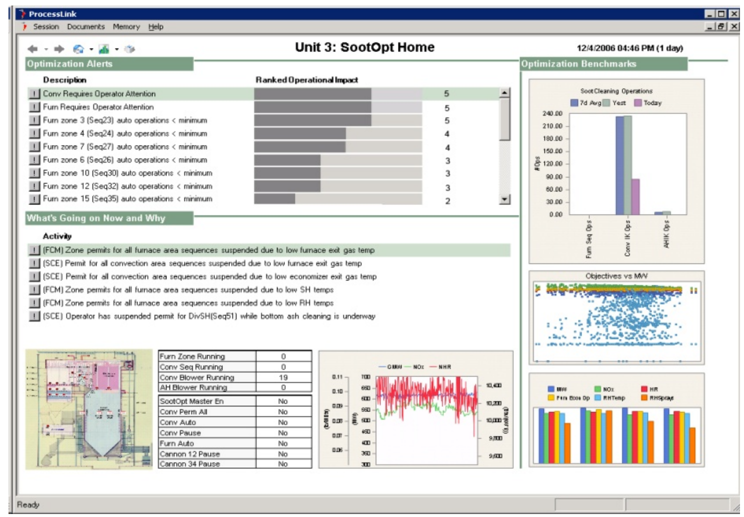
CombustionOpt Analysis

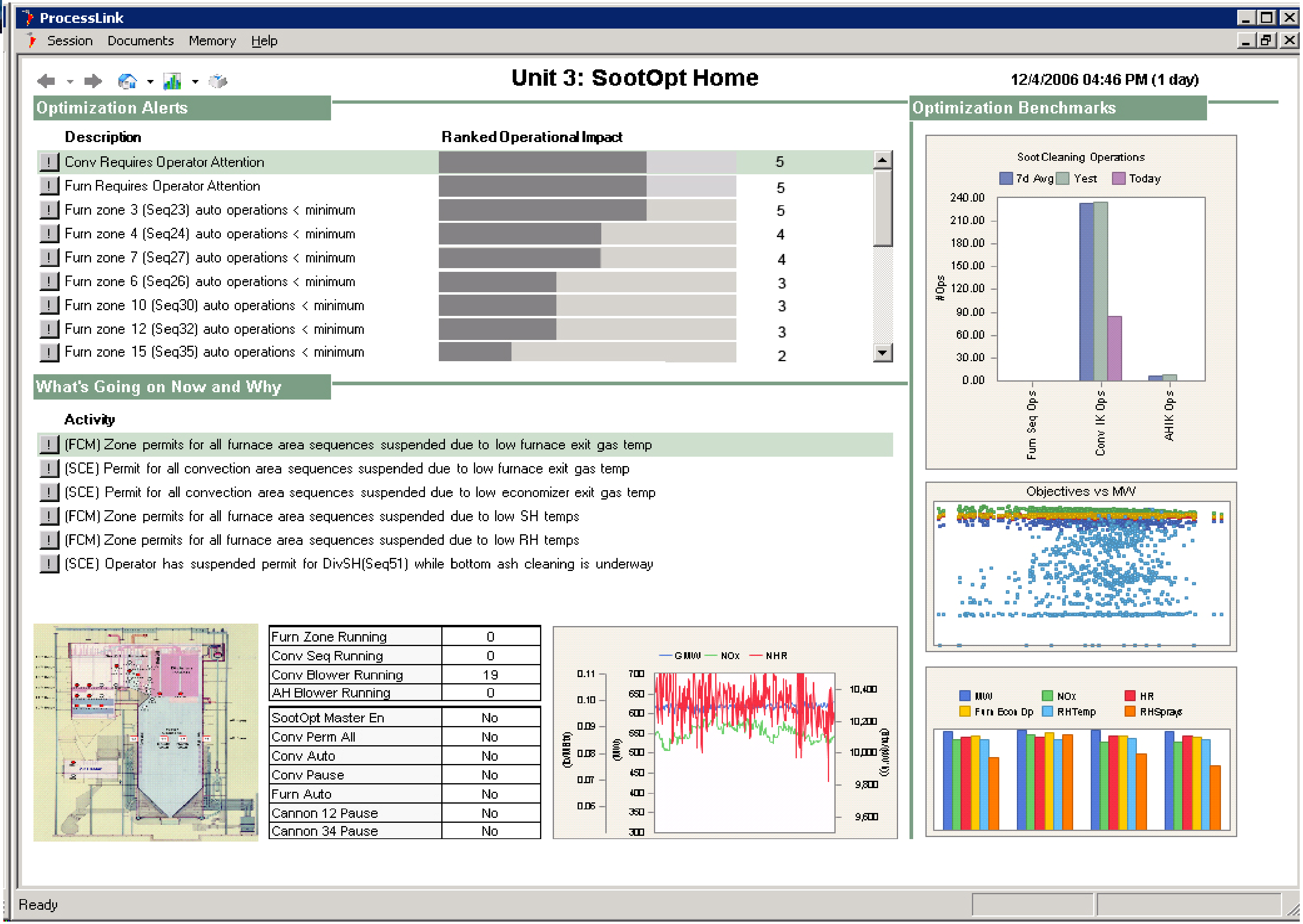


SootOpt Overview

- Context:
  - Sootblowing controls rely on interval-based or operator-initiated cleaning actions, or when using intelligent sootblowing systems, rely on zone cleanliness set points, ignoring the fact that optimal heat transfer requires varying cleanliness over time and across zones
- What SootOpt Does:
  - Provides real-time closed-loop optimization of unit performance by manipulating all relevant sootblowing controls
- Using:
  - Expert systems, neural networks and model predictive control
- To Achieve:
  - Reliability, heat rate, steam temp and emissions improvements



SootOpt Home



ProcessLink

Session Documents Memory Help

Unit 3: SootOpt Analysis

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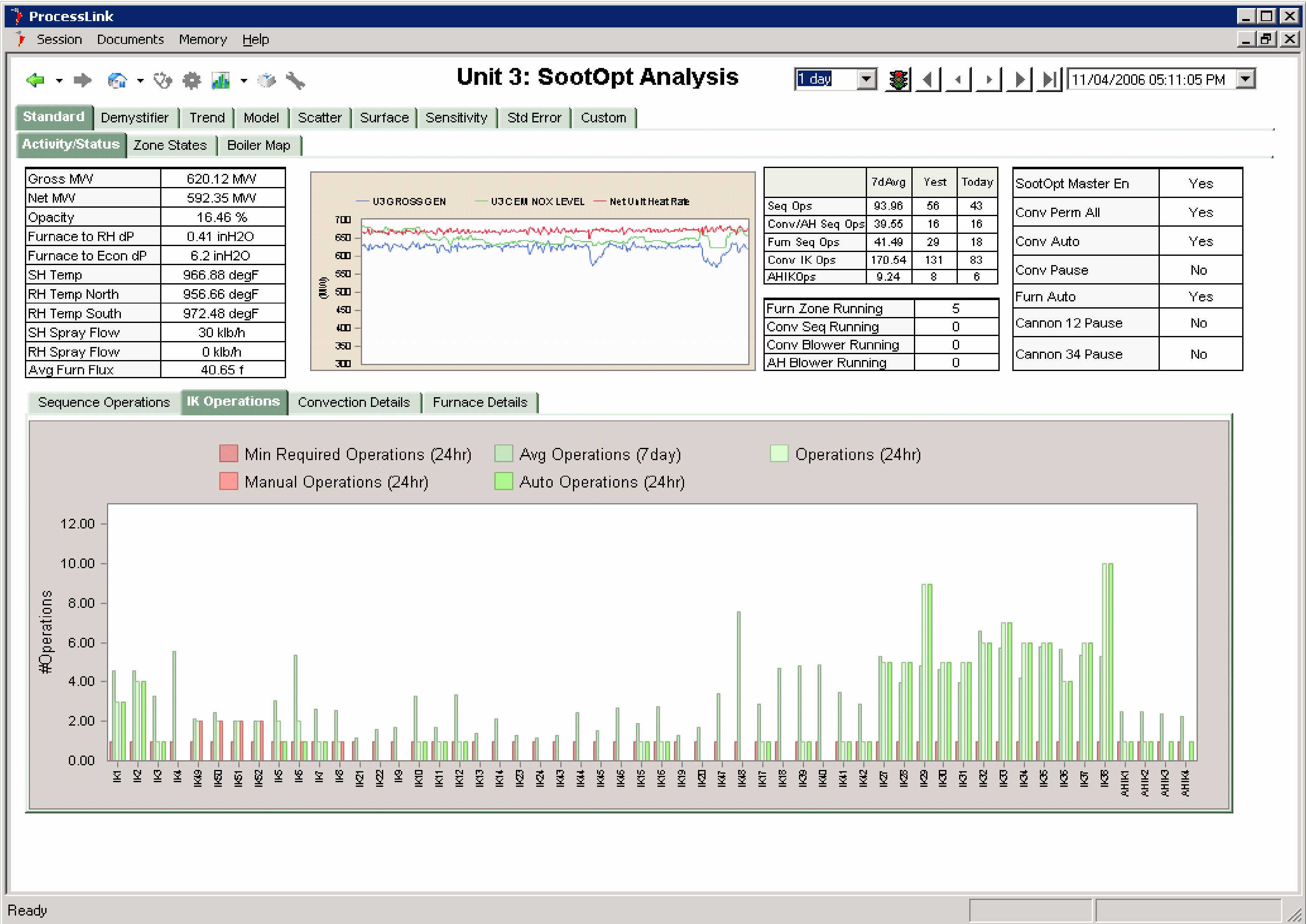
Standard | Demystifier | Trend | Model | Scatter | Surface | Sensitivity | Std Error | Custom

Activity/Status | Zone States | Boiler Map

Zones	IKs
Nose Arch	1, 2
Division Panels	49, 50, 51, 52
Platen SH	3, 4, 5, 6, 7, 8, 21, 22
Reheater	9, 10, 11, 12, 13, 14, 23, 24, 43, 44, 45, 46
Secondary SH	15, 16, 19, 20, 47, 48
Primary SH	17, 18, 39, 40, 41, 42
Economizer	27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38

Ready

SootOpt Analysis



Visibility into Heuristics

ProcessLink

Session Documents Memory Help

Unit 3: SootOpt Analysis

1 day

Standard | **Demystifier** | Trend | Model | Scatter | Surface | Sensitivity | Std Error | Custom

	Sys	Enabled	Active	Min	Actual	Max	Unit
Pause all convection sequences, FEGT violation	SCE	Yes	No	1,900	1,993.1		degF
Pause all convection sequences, load violation	SCE	Yes	No	400	633.8		MW
Pause all convection sequences, EEGT violation	SCE	Yes	No	600	693		degF
Pause all convection sequences, tilts violation	SCE	Yes	No		-0.3	5	%
Pause RH(53), RH spray violation	SCE	Yes	No		23.6	75	klb/h
Pause DivSH(51) and PlatSH(52), RH temp violation	SCE	Yes	No	975	995		degF
Pause Nose(58), RH(53) SH outlet temp violation	SCE	Yes	No	990	990.2		degF
Pause all convection sequences but DivSH(51), DivSH running	SCE	Yes	Yes				
Operator has inhibited DivSH(51)	SCE	Yes	No				
Pause all furnace sequences, tilts violation	FCM	Yes	No		-0.3	5	%
Pause all furnace sequences, FEGT violation	FCM	Yes	No	1,900	1,993.1		degF
Pause all furnace sequences, load range violation	FCM	Yes	No	400	633.8		MW
Pause all furnace sequences, SH outlet temp violation	FCM	Yes	Yes	995	990.2		degF
Pause all furnace sequences, RH spray violation	FCM	Yes	No	5	23.6		klb/h
Pause all furnace sequences, RH outlet temp violation	FCM	Yes	No	975	995		degF
Inhibit convect zones, high opacity	SCE	No	No		19	100	percent
Ihibit convection zones from cleaning while clean	FCM	No	No				
Allow convection to clean while clean, high Dp	FCM	No	No		5.9	6	inH2O
Adjust convection uRatio biases, high Dp	FCM	No	No		5.9	7	inH2O
Request convection clean on time, high Dp	SootOpt	No	No		6	8	inH2O
Inhibit furnace zones from cleaning while clean	SootOpt	No	No				
Allow furnace zones to clean while clean, high RH sprays	SootOpt	No	No		23.6	40 klb/h	klb/h
Adjust furnace flux biases, high RH sprays	SootOpt	No	No		23.6	100	klb/h
Request furnace clean on time, high RH sprays	SootOpt	No	No		23.6	100	klb/h

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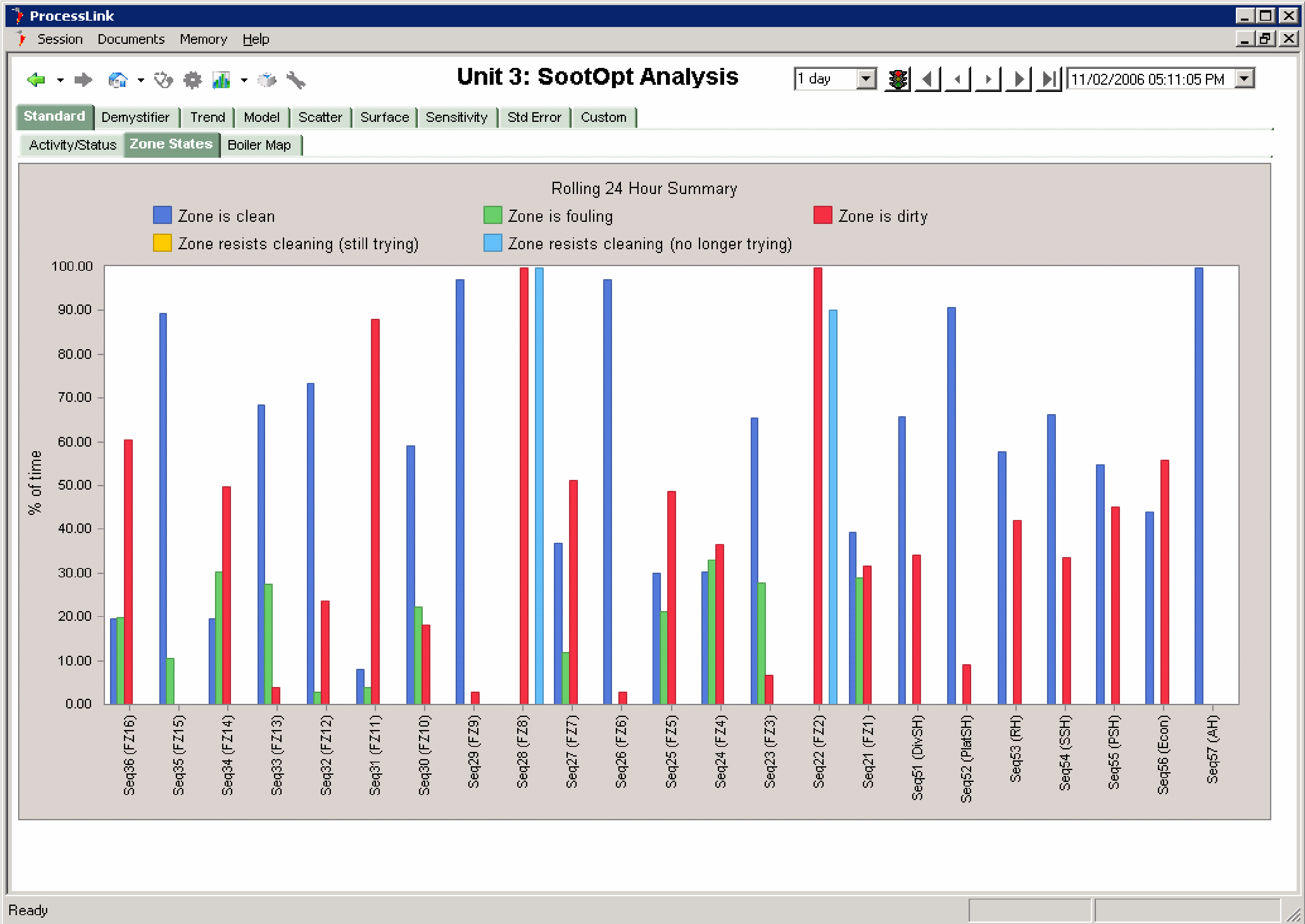
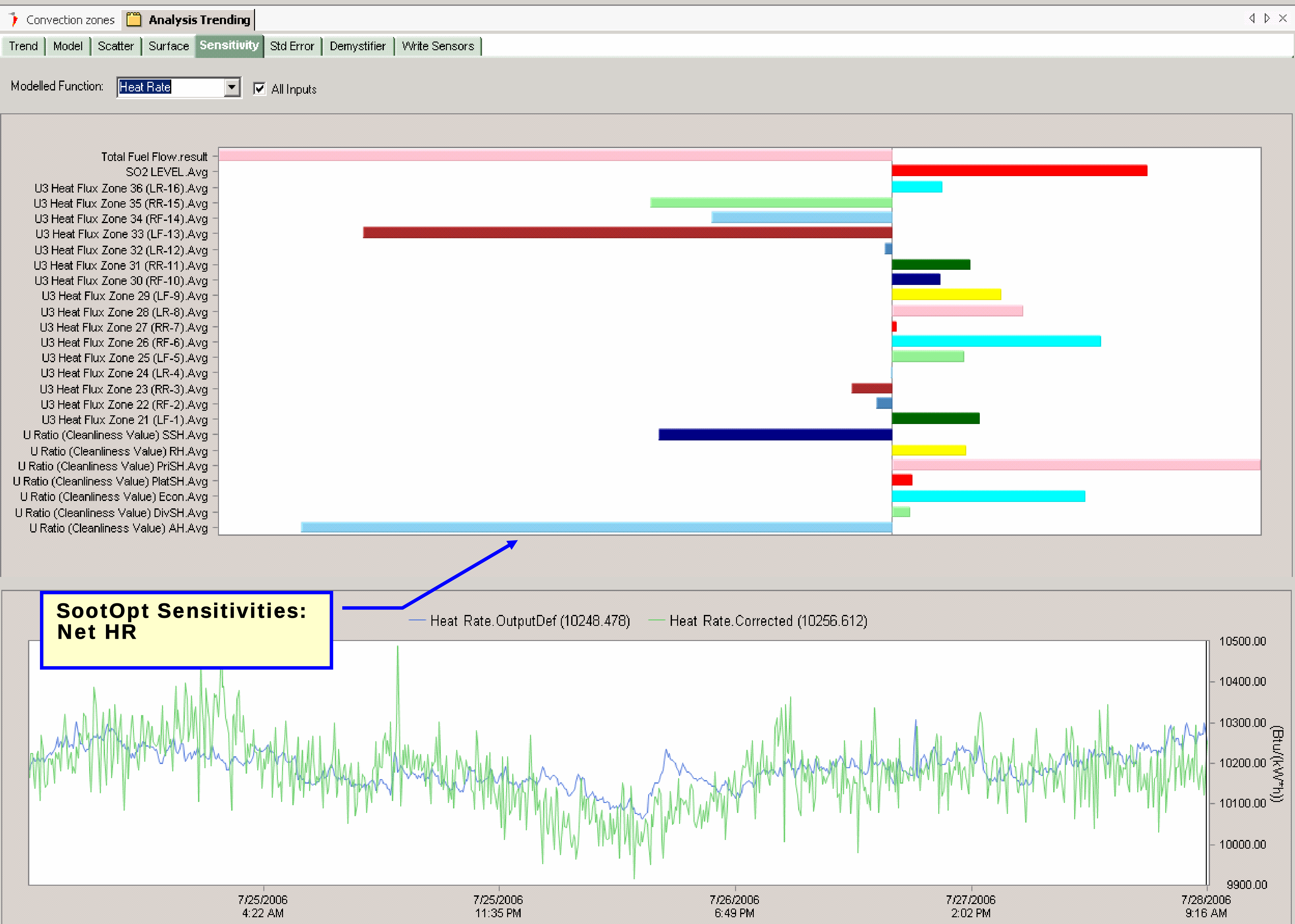
SootOpt Tools




Convection zones
Analysis Trending
Trend
Model
Scatter
Surface
Sensitivity
Std Error
Demystifier
Write Sensors
Modelled Function:
Heat Rate
All Inputs
Total Fuel Flow.result
SO2 LEVEL.Avg
U3 Heat Flux Zone 36 (LR-16).Avg
U3 Heat Flux Zone 35 (RR-15).Avg
U3 Heat Flux Zone 34 (RF-14).Avg
U3 Heat Flux Zone 33 (LF-13).Avg
U3 Heat Flux Zone 32 (LR-12).Avg
U3 Heat Flux Zone 31 (RR-11).Avg
U3 Heat Flux Zone 30 (RF-10).Avg
U3 Heat Flux Zone 29 (LF-9).Avg
U3 Heat Flux Zone 28 (LR-8).Avg
U3 Heat Flux Zone 27 (RR-7).Avg
U3 Heat Flux Zone 26 (RF-6).Avg
U3 Heat Flux Zone 25 (LF-5).Avg
U3 Heat Flux Zone 24 (LR-4).Avg
U3 Heat Flux Zone 23 (RR-3).Avg
U3 Heat Flux Zone 22 (RF-2).Avg
U3 Heat Flux Zone 21 (LF-1).Avg
U Ratio (Cleanliness Value) SSH.Avg
U Ratio (Cleanliness Value) RH.Avg
U Ratio (Cleanliness Value) PriSH.Avg
U Ratio (Cleanliness Value) PlatSH.Avg
U Ratio (Cleanliness Value) Econ.Avg
U Ratio (Cleanliness Value) DivSH.Avg
U Ratio (Cleanliness Value) AH.Avg
SootOpt Sensitivities: Net HR
Heat Rate.OutputDef (10248.478)
Heat Rate.Corrected (10256.612)
10500.00
10400.00
10300.00
10200.00
10100.00
10000.00
9900.00
(Btu/(kW*h))
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Agenda

- Optimization Overview
- Components of Integrated Boiler Optimization
- **Boiler Optimization Project at Baldwin**

Dynegy's Baldwin Energy Complex

3 - 600 MW Units

1970-1975

Units 1 & 2 Cyclone Fired

14 Cyclones/Unit

Unit 3 Tangential-Fired

6 Mills

PRB Coal

Conversions
1999 & 2000

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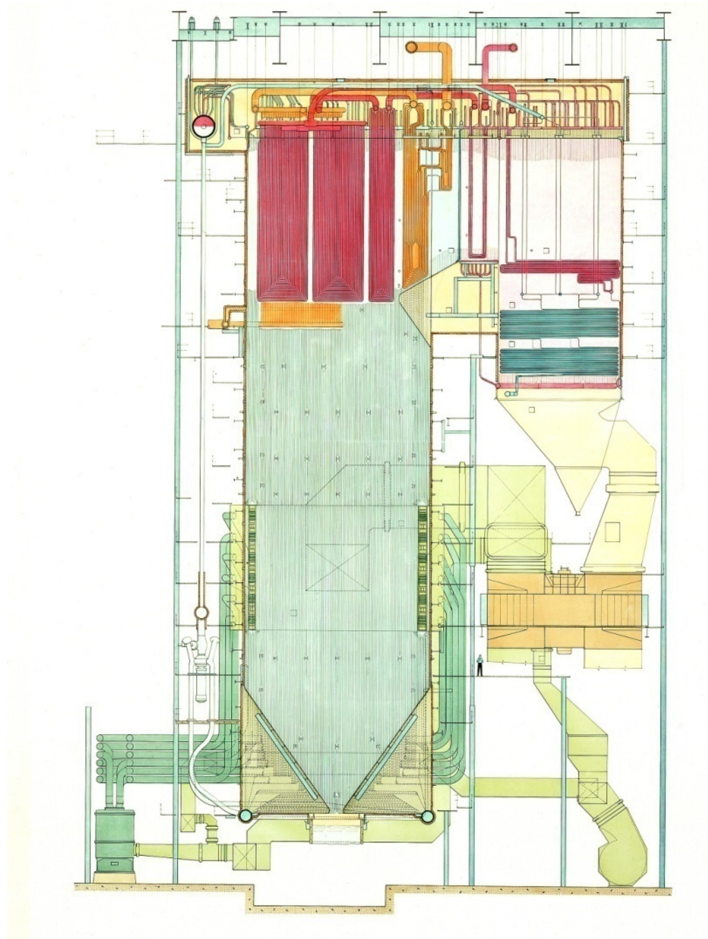
NeuCo's CCPI Project @ Baldwin

- About the Clean Coal Power Initiative (CCPI)
  - $1.3 B initiative to demonstrate clean coal technologies in the field
  - Sponsored by DOE's National Energy Technology Laboratory
  - NeuCo's project at Baldwin selected as Round 1 winner in 2004
- Five integrated optimization modules, parallel development
  - SCR
  - **Combustion**
  - **Soot blowing**
  - Performance
  - Maintenance
- Products developed iteratively with multiple releases

Baldwin Unit 3

- CE Drum-type Boiler
- Pulverized T-Fired: Six Pulverizers
- Furnace Dimensions: 52' x 58', 180' tall
- SOFA, Low NOx Burners
- Steam Conditions
  - Flow: 4.2 MLb/Hr
  - SH/ RH Temperature: 1005F/1005F
  - Throttle Pressure: 2425 Psig



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Motivations for Optimization

- Full Load PRB operation requires tight control
  - Loss of spare mill at full capacity
  - Small process changes have significant effects
  - Seasonal impacts to heat rate

- Expectations
  - Ability to control key parameters on consistent basis
  - Ability to compensate for changes in coal quality
  - Improved understanding of available data and its use for improved operations
  - Ability to optimize controls to meet plant objectives

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Initial CombustionOpt Benefits

- Reduction in NOx average and variability
  - BEC Unit 3 already one of the lowest NOx coal-fired units in North America
- Increased process knowledge
- Improved consistency across operators and shifts
- Empirical validation of boiler cleanliness interactions

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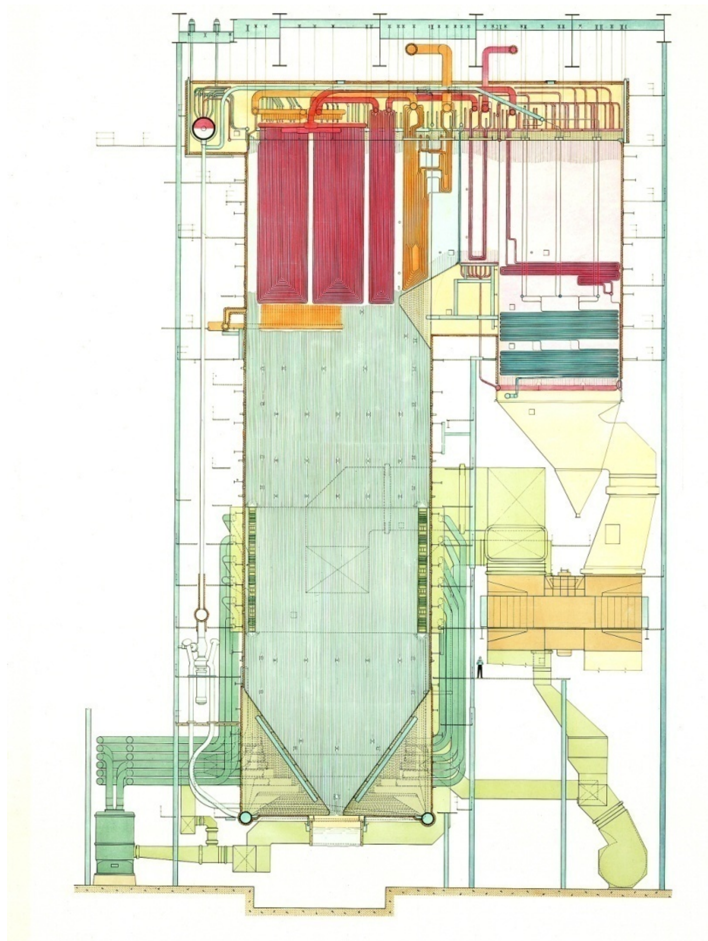
Unit 3 Sootblowing Operation prior to SootOpt

- High variability in PRB coal
- Water Cannons and Heat Flux Sensors in Furnace area
- PrecisionClean and standard IK's in convection pass
- Diamond (ASI) control system to operate water cannons & sootblowers
- Prevailing sootblowing guidelines:
  - Water cannons operator initiated when attemperation sprays high
  - Operator initiated sequences in the convection pass – normally a sequence of most IK's running continuously
  - Monitor furnace-to-economizer and furnace-to-reheater differential pressures; Increase sootblowing if differentials increase

Baldwin 3 – Ash Deposition

- PRB Coal
  - Intermittent Wall Deposition
  - Division Panels
  - SH Pendant
  - Horizontal SH



ISB & SootOpt installation @ Unit 3

- Upgraded sootblowing controls to Diamond SentrySeries 1500 Intelligent Sootblowing Control System (ISB)
- Added thermocouples and thermo-probe behind pendent reheater for heat transfer calculations
- Installed NeuCo's SootOpt for adaptive optimization of sootblowing operation
- Integrated SootOpt with Diamond furnace (FCM), backpass (SCE) and Automatic Interface module (AIM)

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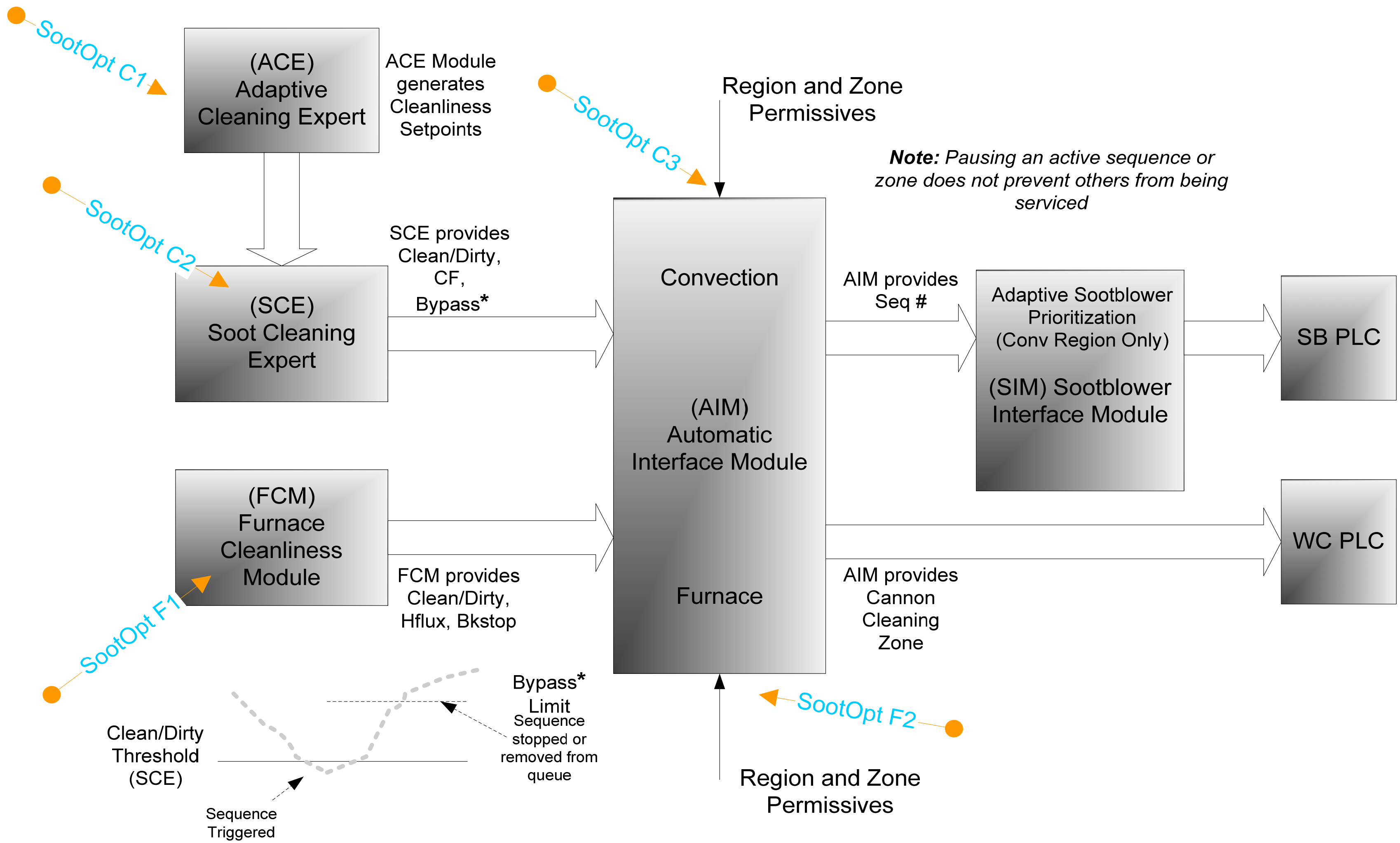
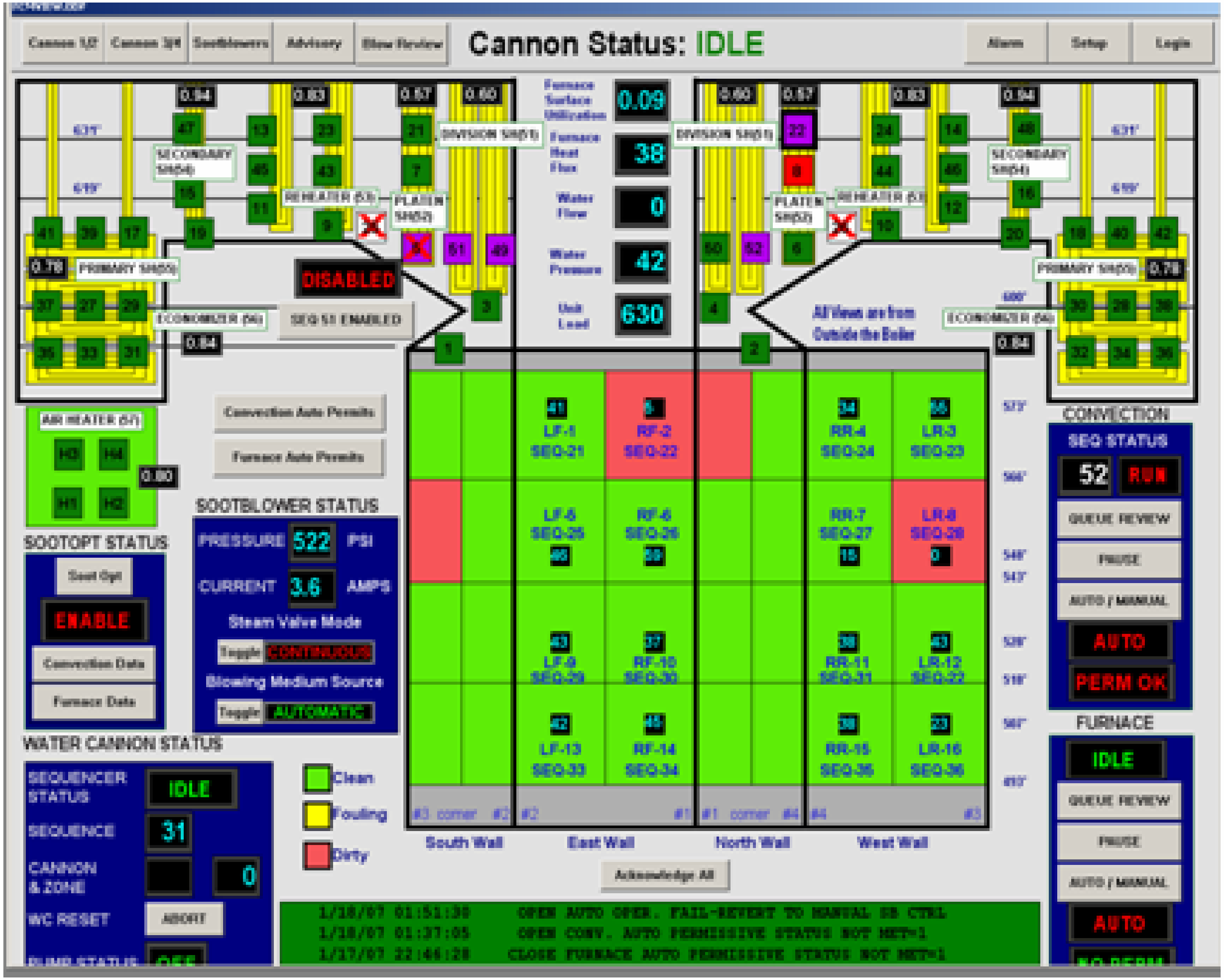
SootOpt - Diamond SentrySeries 1500 Interface



Diamond Intelligent Sootblowing System



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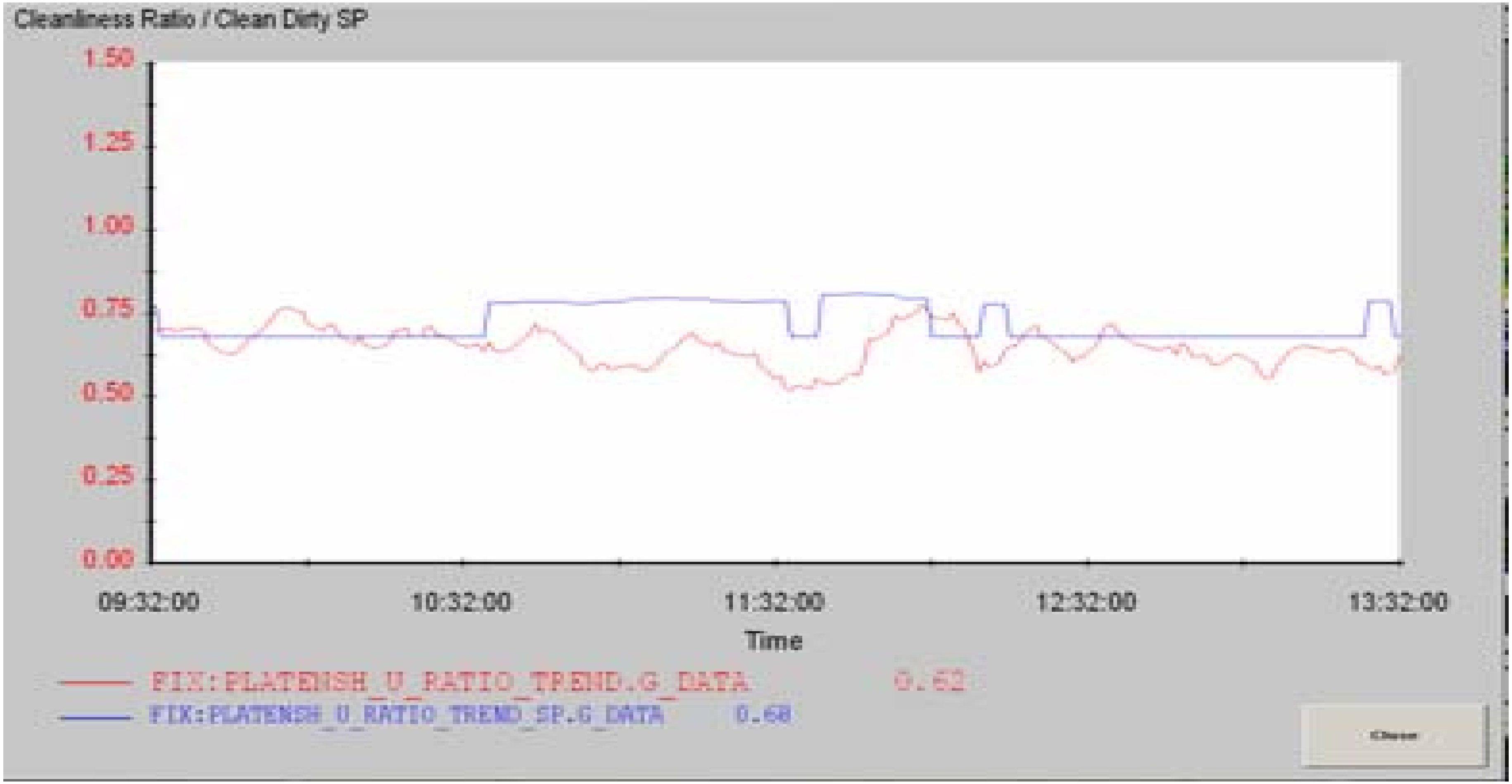
SootOpt/ISB Interaction



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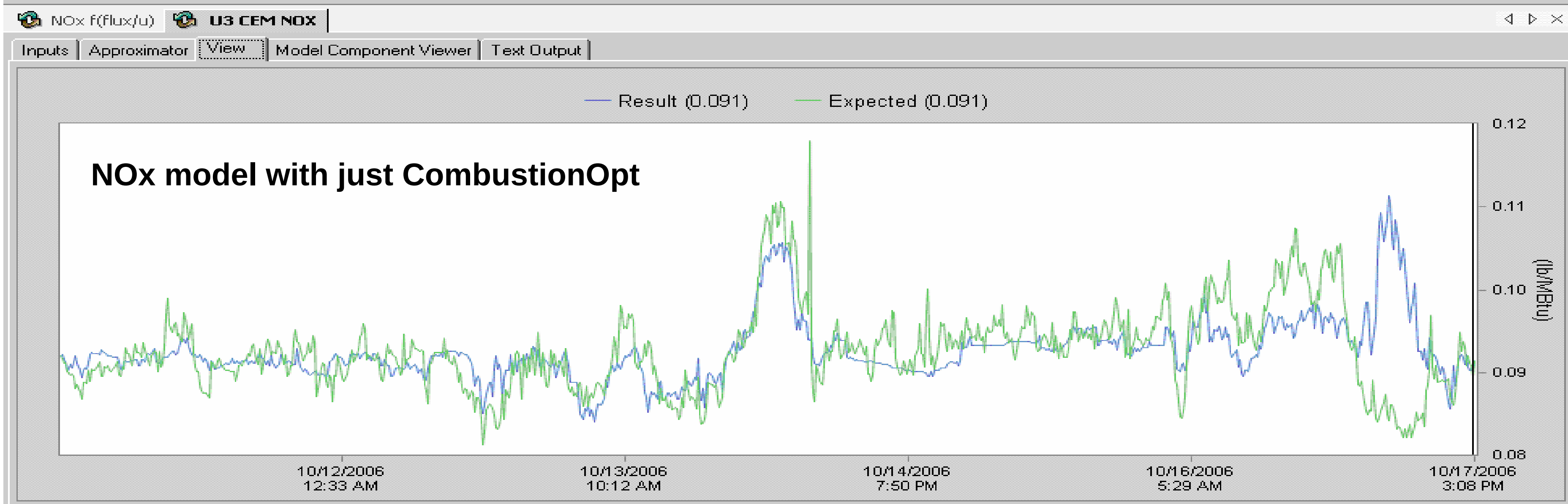
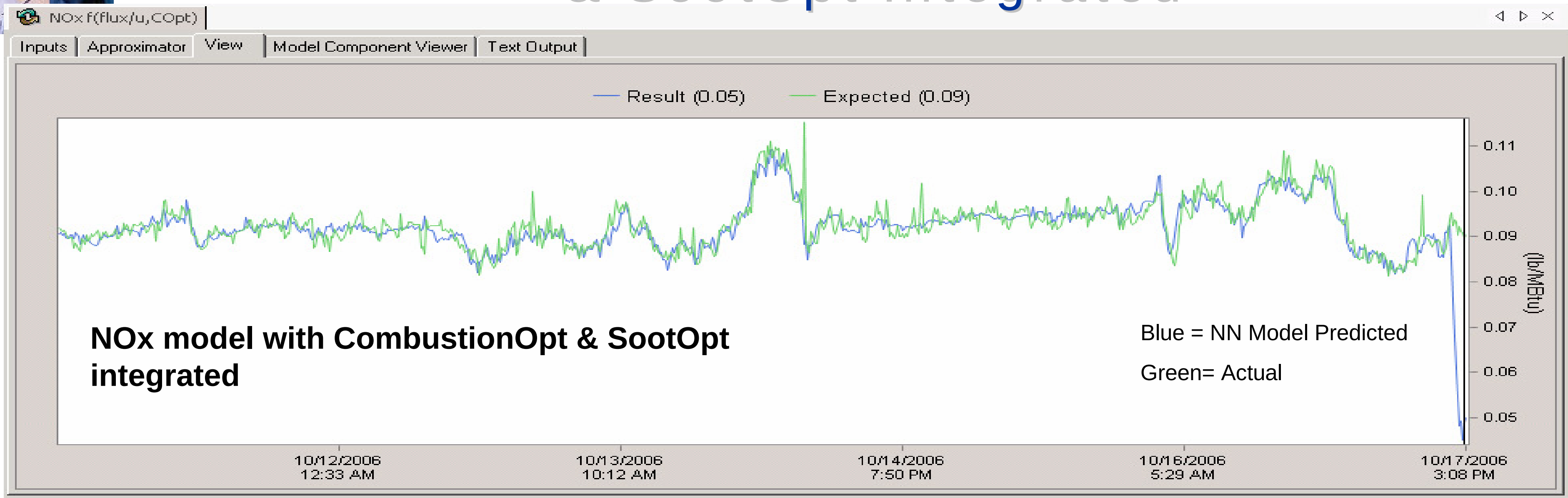
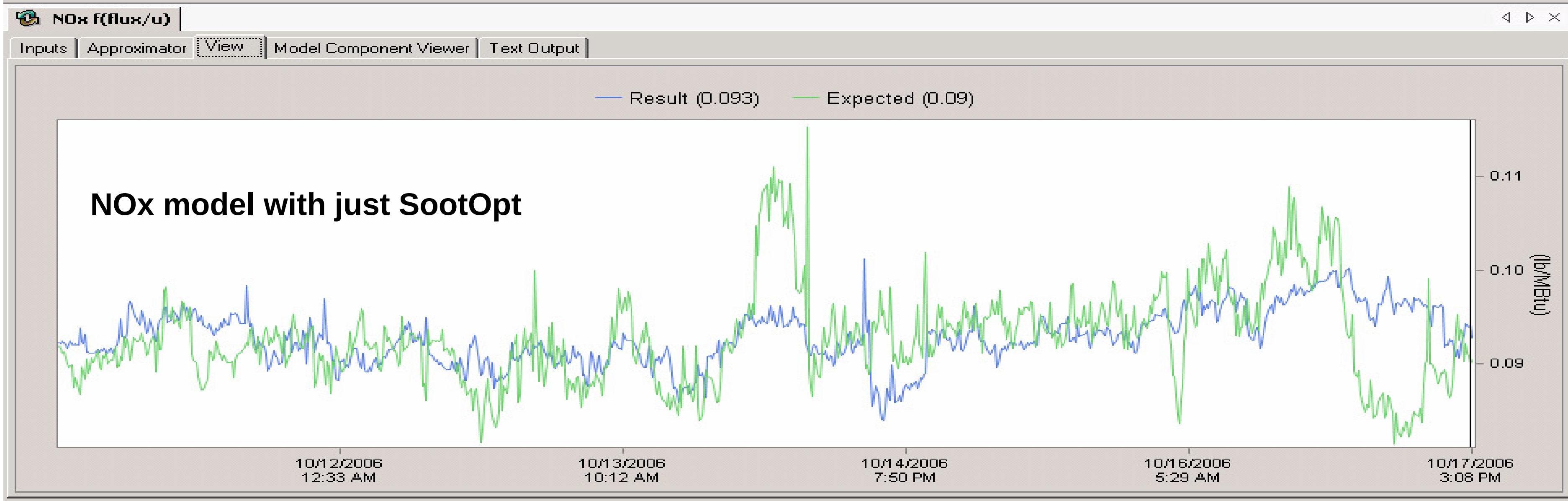
Improved Model Fidelity with CombustionOpt & SootOpt Integrated

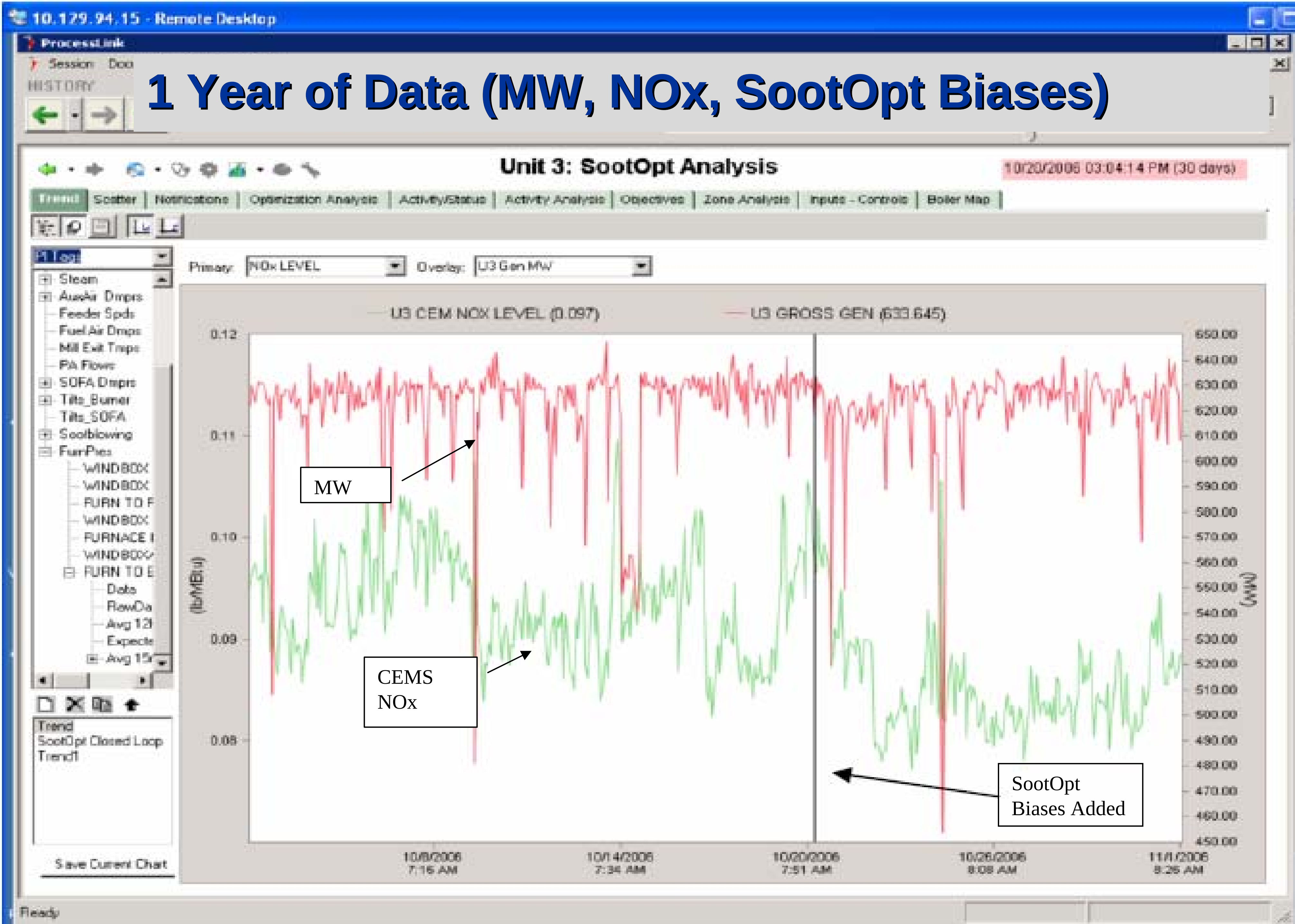


Improved Model Fidelity with CombustionOpt & SootOpt Integrated

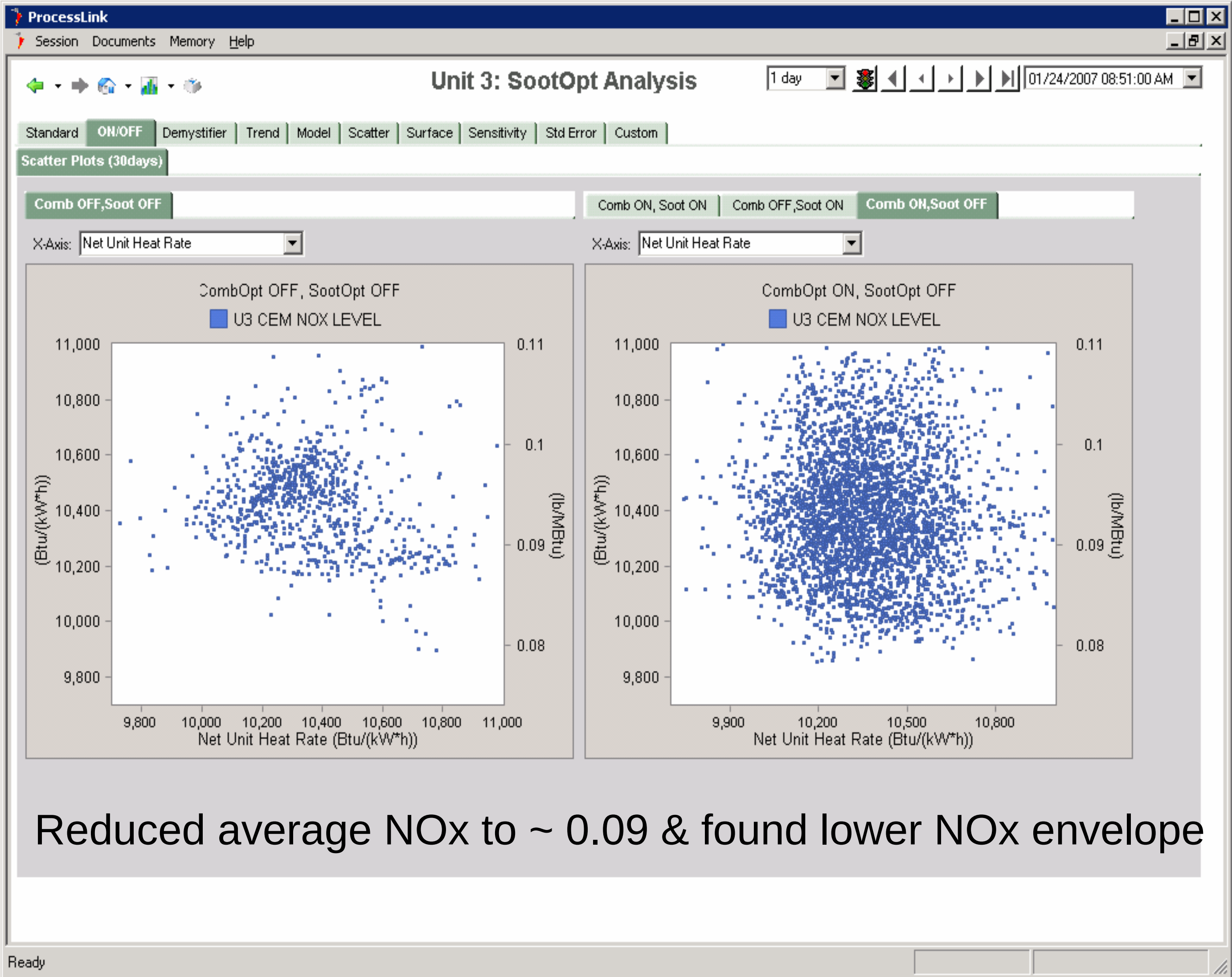




1 Year of Data (MW, NOx, SootOpt Biases)

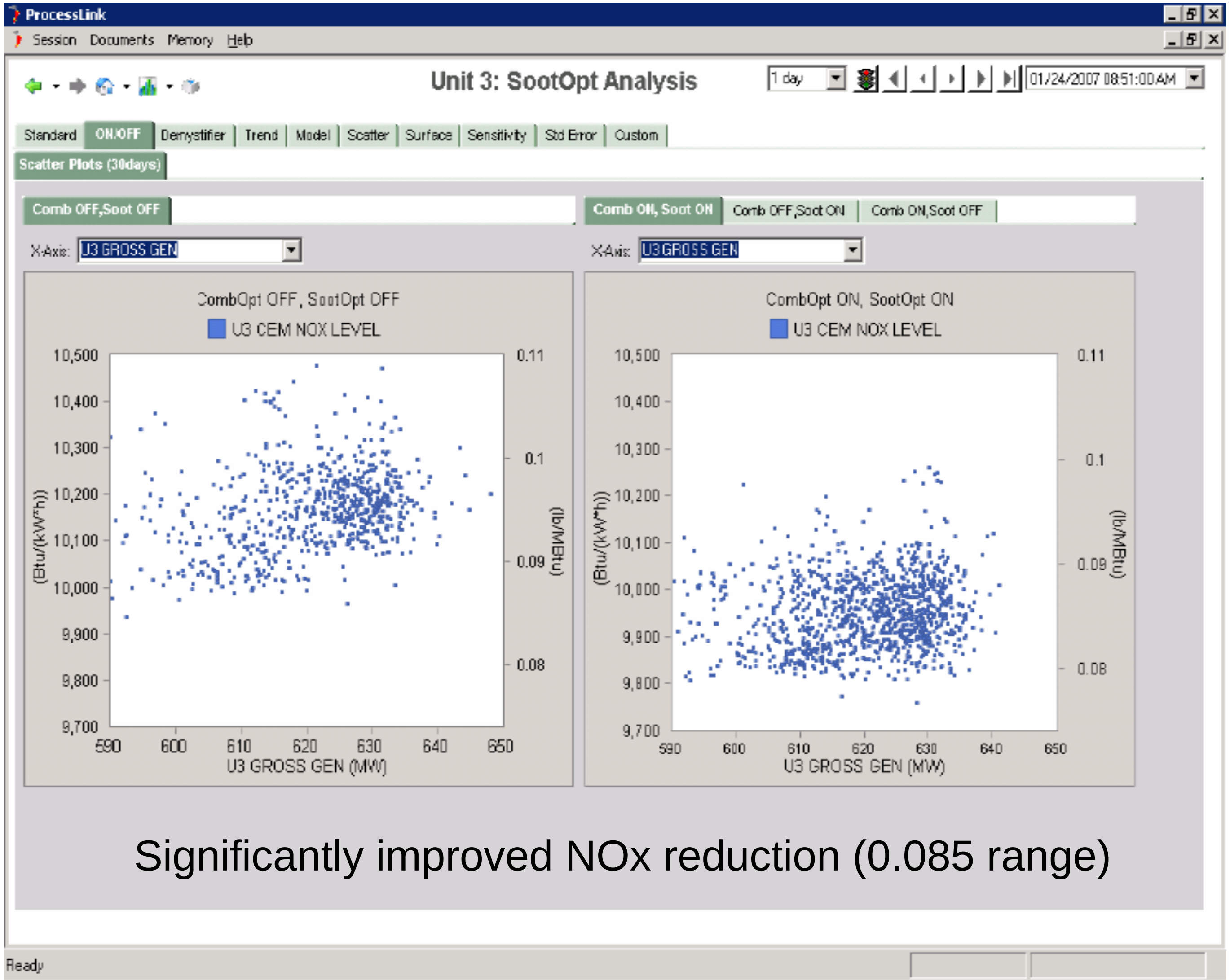


CombustionOpt Impact on NOx



Reduced average NOx to ~ 0.09 & found lower NOx envelope

Combined Impact on NOx



Significantly improved NOx reduction (0.085 range)

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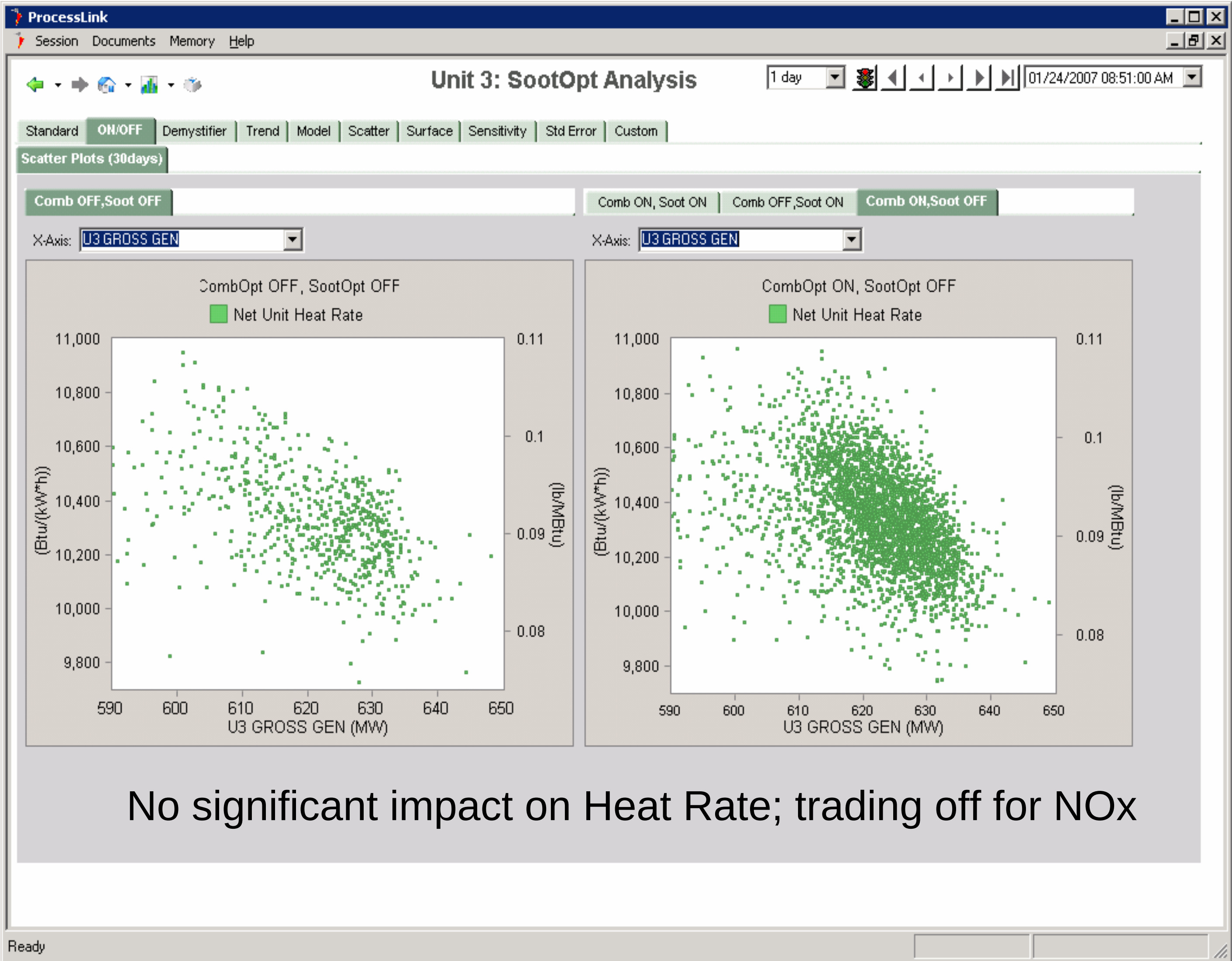
CombustionOpt Impact on Heat Rate



No significant impact on Heat Rate; trading off for NOx

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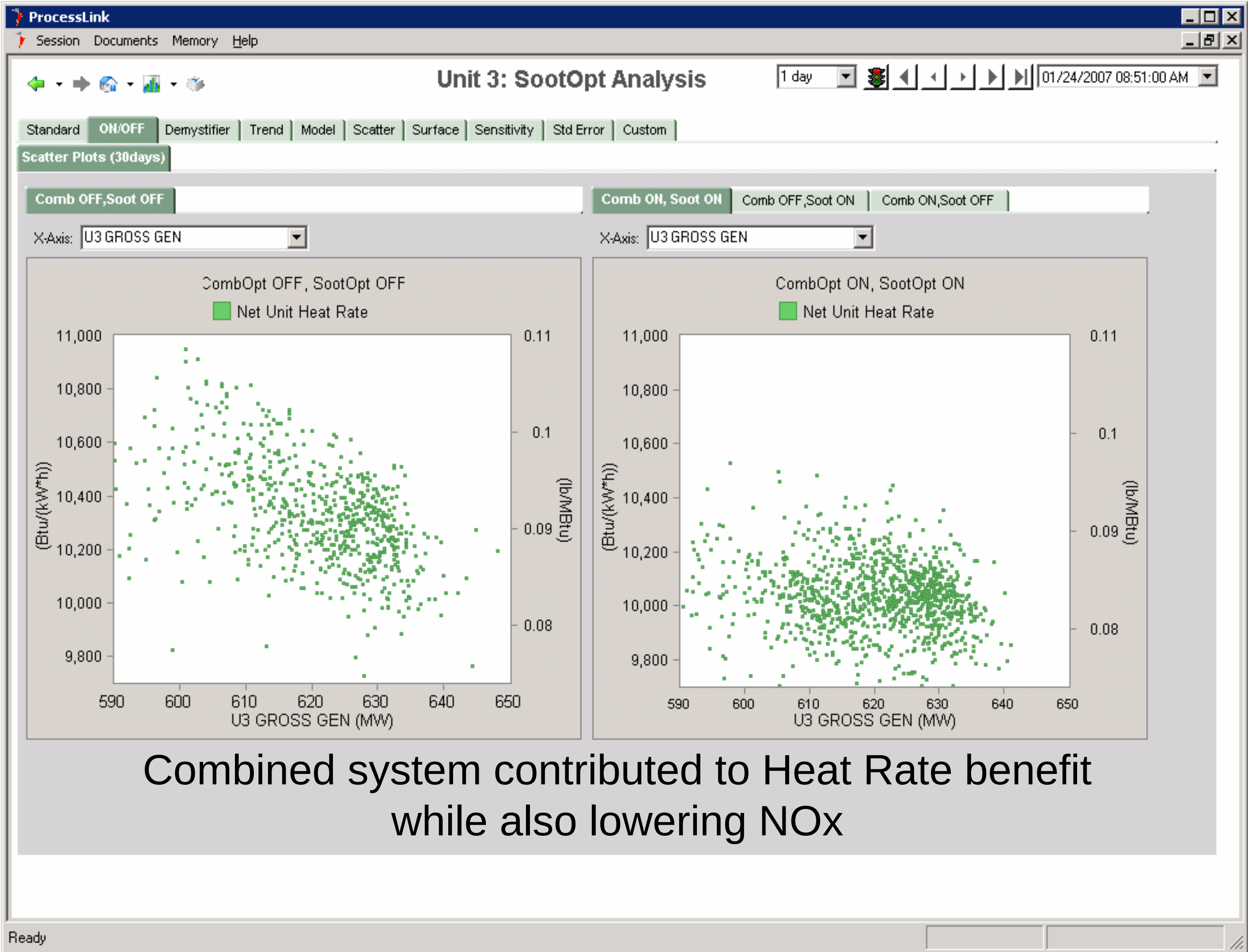
Combined Impact on Unit Heat Rate



Combined system contributed to Heat Rate benefit while also lowering NOx

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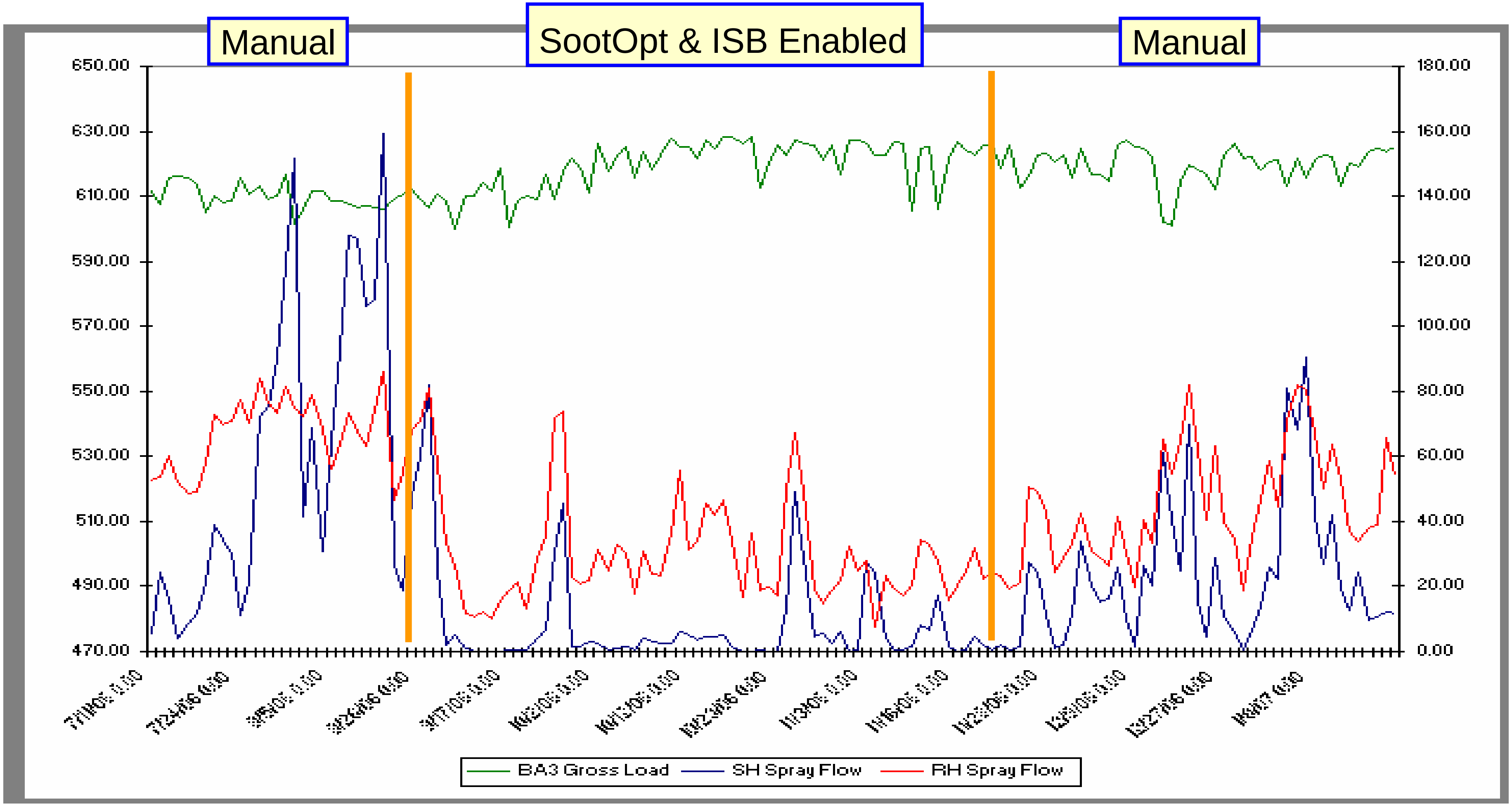
Average Daily Attemperation Spray Flows



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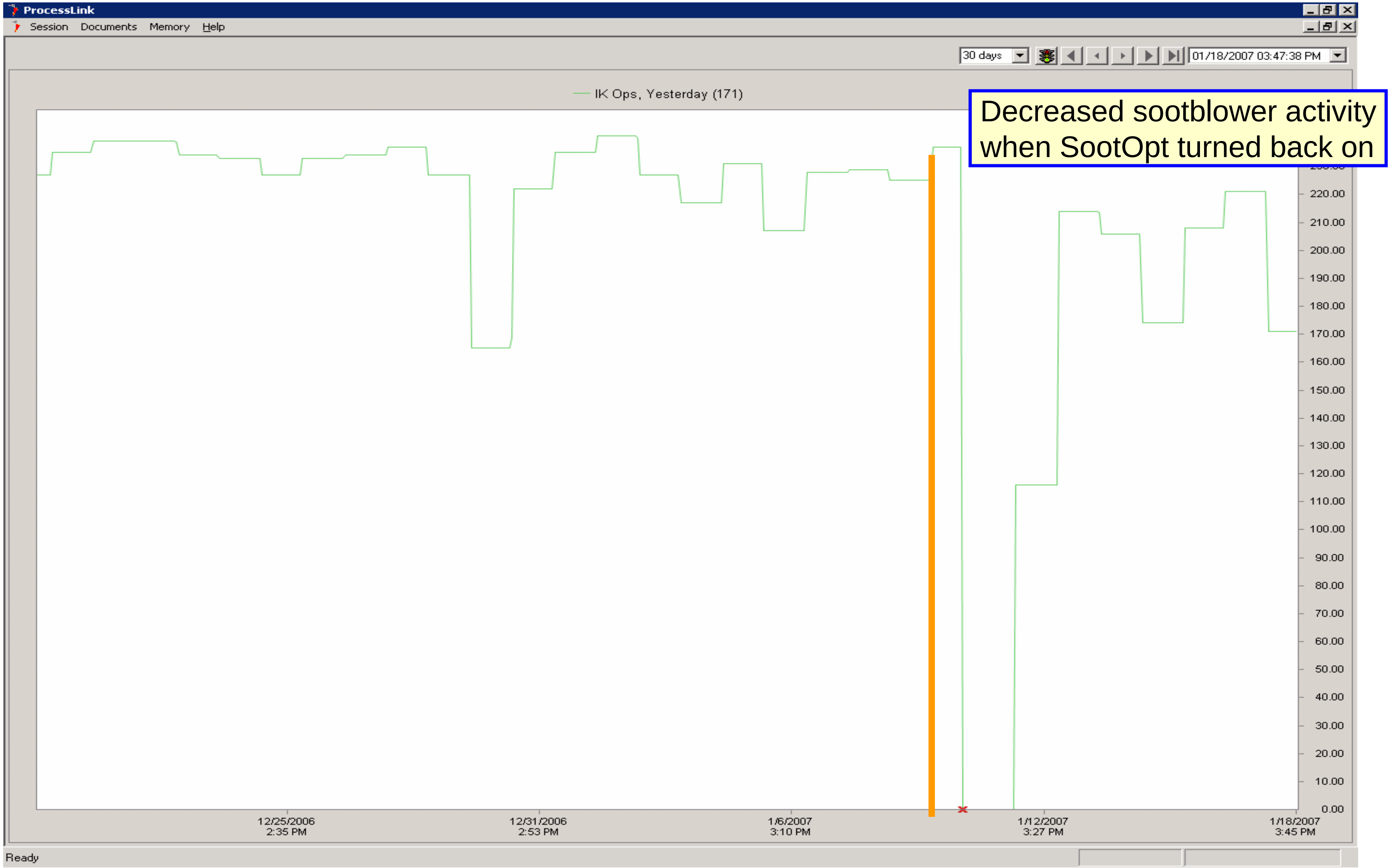
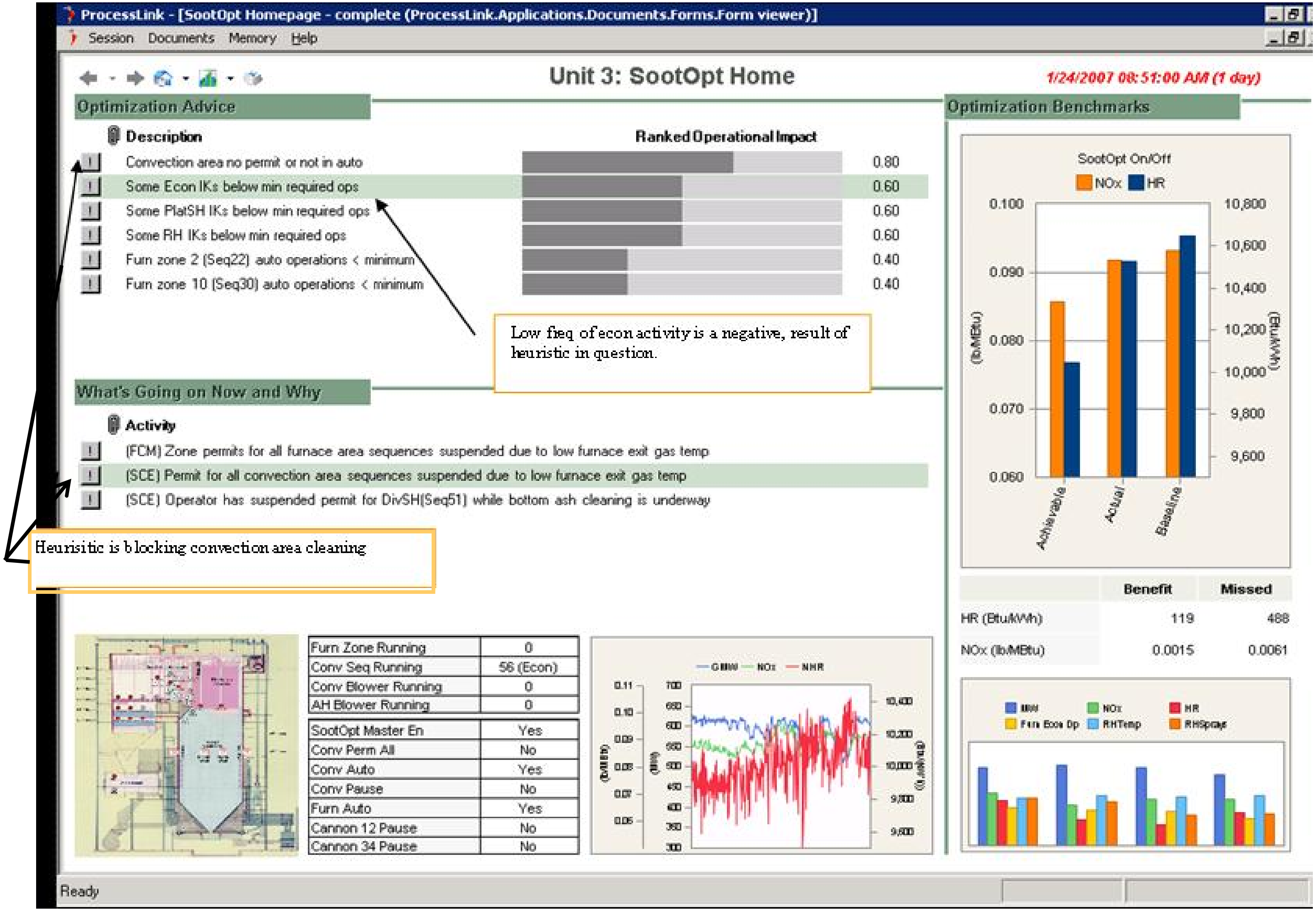
IK Activity Manual vs ISB/SootOpt



SootOpt Helps Detect Underlying Problems:

Increased Furnace/Convection Pauses Due to FEGT < 1900 f.



Boiler Optimization Results Thus Far

- Improved NOx and Heat Rate with decreased variability
- Decreased sootblower operation count
- Attemperation spray flows controlled to less than 50 klbhr with SootOpt/ISB whereas before spray flows would at times be above 100 klbhr
- Initially split in attemperation flow control caused steam temps drop to 950F which could effect MW output. Recent changes have reduced that drop to 980F
- Provided early detection into anomalies in ISB activity caused by instrumentation failure
- Improved transparency into complex behavior of ISB
- Real-time tradeoffs between objectives and performance benchmarking

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Looking Ahead

- Complete Integration of CombustionOpt and SootOpt and at Unit 3
- Complete installation of SootOpt on Unit 2
- Integrate CombustionOpt, SCR-Opt, SootOpt, PerformanceOpt and MaintenanceOpt at Unit 2
- Further refine CombustionOpt, PerformanceOpt & MaintenanceOpt at Unit 1
- Further refine Unit and Plant Advisors
- Subsequent refinement and releases based on feedback from Baldwin and other NeuCo Showcase sites